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Standard Reference Materials:

DESCRIPTION AND USE OF PRECISION THERMOMETERS FOR THE CLINICAL LABORATORY, SRM 933 AND SRM 934

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Standard Reference Materials:

Description and Use of Precision Thermometers for the Clinical Laboratory, SRM 933 and SRM 934

B. W. Mangum and J. A. Wise

Heat Division
Institute for Basic Standards
National Bureau of Standards
Washington, D.C. 20234

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STANDARD REFERENCE MATERIALS: DESCRIPTION AND USE OF PRECISION THERMOMETERS FOR THE CLINICAL LABORATORY, SRM 933 and SRM 934

by

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Because of the high sensitivity to temperature of many facets of the clinical laboratory, e.g. in enzyme reactions and in pH and blood gas analysis, there is a need for accurate temperature measurement and its control. In order to help satisfy these needs and to aid in getting a usable and accurate temperature scale into the clinical laboratory, the National Bureau of Standards has developed SRM 933 and SRM 934. These are precision thermometers, which are calibrated at 0 °C, 25 °C, 30 °C, and 37 °C and their description, their calibration, and the procedures for their proper usage are discussed.

Key words: Clinical laboratory; enzymology; health care; liquid-in-glass thermometers; standard reference material; SRM 933; SRM 934; thermometers.

I. INTRODUCTION

The accurate measurement and control of temperature is of critical importance in many aspects of the clinical laboratory and in the hospital in general. The temperatures at which enzyme rate analyses are conducted, for example, are very important because of their high sensitivity to this parameter [1-4]. Furthermore, in order to obtain reproducible results within a given clinical laboratory and in order to make a meaningful intercomparison among laboratories, the temperature not only must be care-

fully controlled but must be known absolutely. In recognition of this situation, the Expert Panel on Enzymes, which was created by the International Federation of Clinical Chemistry Committee on Standards, has recommended [5], among other suggestions in their Proposal for I.F.C.C. Reference Methods for Enzymes, that the set point in degrees Celsius of the reaction temperature is to be assigned as a part of the method, that the temperature accuracy must be assured to $\pm$ 0.05 °C by calibration against the International Practical Temperature Scale of 1968 [6], that the temperature variation of the reaction mixture should be held within the open interval -0.05 °C and +0.05 °C of the set point, and that the choice of reaction temperature for an IFCC reference method should be either 25.00, 30.00 or 37.00 °C. Of course, enzyme reactions are not unique in being sensitive to the temperature; pH and blood gas analysis are two others in a long list that could be mentioned [1].

Because of these needs and in order to assist in getting a usable temperature scale into the clinical laboratories (and hospitals generally), NBS is providing precision laboratory thermometers, SRM 933 and SRM 934, designed specifically for use in the clinical laboratory. These SRM's, were produced in cooperation with the Medical Thermometry Program of the Temperature Section in the Heat Division. Many specifications requested by clinical laboratory personnel concerned with accurate temperature measurements have been incorporated in the design.

II. DESCRIPTION OF SRM 933 AND SRM 934 THERMOMETERS

The three thermometers comprising SRM 933 are shown in figure 1 and the linear dimensions of the thermometers are as indicated. These are solid-stem mercury-in-glass type instruments. In order to clarify potential problems in terminology, the principal features of a solid-stem liquid-in-glass thermometer are shown in figure 2. The stems have a plain front, enameled back, and are of lead glass thermometer tubing 7 mm in diameter. The bulbs are also 7 mm in diameter. Nitrogen gas fills the space above the mercury. Special markings consist of a serial number, the namufacturer's name or trade mark, and a 95 mm immersion line.

Each thermometer has an auxiliary scale from -0.20 °C to +0.20 °C with 0.05 °C subdivisions. The main scale of the thermometer on the left of figure 1 is 24.00 °C to 26.00 °C with 0.05 subdivisions, that for the thermometer in the middle is 29.00 °C to 31.00 °C with 0.05 °C subdivisions, and that for thermometer on the right of figure 1 is 36.00 °C to 38.00 °C with 0.05 °C subdivisions. The graduations have longer lines at intervals of 0.10 °C and 0.50 °C. In addition, there are numbers every 1 °C. These three thermometers are packaged in one box.

SRM 934 is comprised of the one thermometer shown in figure 3 and its linear dimensions are as indicated. Except for the main scale, which is 24.00 °C to 38.00 °C with 0.05 °C subdivisions, and its overall length, the specifications of this thermometer are the same as those for SRM 933.

III. CALIBRATION OF THE THERMOMETERS

Each thermometer was tested at the ice point (0 °C) by placing it in an ice bath and at the temperatures above 0 °C by placing it in a stirred-liquid comparison bath [7]. Calibrations were performed at 0 °C, 25 °C, 30 °C, and 37 °C and the temperatures were determined by a standard precision platinum resistance thermometer [8] which was also in the comparison bath. The temperature of the calibration laboratory was 23 °C. The thermometer was read with the aid of a 10 power telescope, which was placed perpendicularly to the thermometer in order to reduce parallax errors. Before each reading, the mercury thermometer was gently tapped to eliminate any error due to a sticking mercury column. The maximum error associated with any calibration point is no greater than 0.03 °C.

IV. PROCEDURES FOR PROPER USAGE OF LIQUID-IN-GLASS THERMOMETERS

The items discussed in this section are included to focus attention on some of the more common problems encountered in the use of liquid-in-glass thermometers and thus to help assure that the thermometer will be

used properly and, thereby, will yield the desired performance. All examples in this paper are given as an aid in the understanding of the subject being discussed, and have not been specifically adapted to the individual thermometers of SRM 933 and SRM 934.

A. CHECK FOR SEPARATED MERCURY COLUMNS AND FOR GAS BUBBLES

Many times, because of rough handling during shipment, separation will occur in the mercury column or gas bubbles will appear in the bulb. When the thermometer is received it should be throughly examined for such occurrences.

The process of joining separated mercury columns consists of one or a series of manipulations:

a) The bulb of the thermometer may be cooled in a solution of common salt, ice, and water (or other cooling agent) to bring the mercury slowly down into the bulb. Only the bulb should be cooled and never the stem or mercury column. Moderate tapping of the bulb on a rubber stopper or similar soft spongy object, or the application of centrifugal force by swinging the thermometer in a short arc, usually serves to unite the mercury in the bulb. If the salt solution does not provide sufficient cooling, carbon dioxide snow (dry ice) may be used. Since the temperature of dry ice is about -78 °C and mercury freezes at about -39 °C, the mercury will solidify. On warming, care must be taken to warm the top of the bulb first so that pressures in the bulb due to the expanding mercury may be relieved.

b) The mercury can sometimes be reunited by warming the bulb until the column reaches the separated portion in either the contraction chamber or the expansion chamber. If this procedure is used, the bulb should never be heated in an open flame. Great care is necessary to avoid filling the expansion chamber completely with mercury which might produce pressures great enough to burst the bulb. The expansion chamber should never be more than two thirds full. Joining the mercury is more readily accomplished if the quantity in either cavity has first been shattered into droplets by tapping the thermometer laterally against the hand.

Gas bubbles, which are sometimes found along the surface of the mercury in the thermometer bulb, may be collected by "washing" the bulb with a large gas bubble. As outlined in section (a) above, bring all of the mercury into the bulb. Hold the thermometer in a horizontal position and gently tap it against the hand to form a large gas bubble. Force the bubble to travel around the walls of the bulb by rotating the thermometer and tapping it against the palm of the hand. When the entire surface has been "washed", rotate the bubble to the top of the bulb and reunite the mercury as described above.

All of these manipulations require patience (and experience is helpful) but they will yield the desired results if care is used. A convenient method of ascertaining that all the mercury has been joined is a check of the ice point. It should agree with the ice-point reading on the Report of Calibration by within approximately one scale division or better.

B. ICE POINT DETERMINATION

The ice point, known as a reference point, is found on the auxiliary scale. It is a temperature that can be easily duplicated in any laboratory and is used to check the thermometer periodically for changes in bulb volume.

To make an ice bath, a Dewar flask may be used as a container, since the insulating properties of the vessel retard the melting of ice. Ice shaved from clear cakes or from that made with distilled water is mixed with distilled water to form a tightly packed slush. Enough water is used to afford good contact with the thermometers but not so much as to float the ice. At periodic intervals excess water is siphoned from the bath. Care should be taken to prevent contamination of the ice and water. Any change in the ice point will be reflected in the other calibration points by the same amount and in the same direction. An example is given below:

Original Corrections From NBS Report

Temperature	Correction
-0.013 °C	+0.013 °C
25.000 °C	+0.010 °C
30.000 °C	+0.008 °C
37.000 °C	+0.015 °C

A later ice-point reading, taken after the thermometer has been at a temperature of about 23 °C for not less than three days, may be -0.020 °C. This means that the ice-point correction will be +0.020 °C and a new set of corrections should be made by adding +0.007 to all of the original corrections. The new table would look as follows:

Temperature	Correction
-0.020 °C	+0.020 °C
25.000 °C	+0.017 °C
30.000 °C	+0.015 °C
37.000 °C	+0.022 °C

Because of bulb expansion, a temporary ice point depression will be introduced when the thermometer is heated above room temperature (23 °C). Because of this depression, the thermometer should never be used at a given temperature shortly after it has been heated beyond that temperature. An error of 0.01 °C or less for each 10 °C difference between the two temperatures may be introduced. If the thermometer has been heated beyond the temperature at which it is to be used and if the corrections are to be used as given on the Report of Calibration, it must be kept at room temperature (approximately 23 °C) for not less than three days to assure recovery of the bulb.

A small reading telescope with a magnification of 10 diameters aids in reading the thermometer indication and reduces parallax errors. Gently tapping the thermometer just before reading may prevent the sticking of a falling meniscus. On the other hand, too vigorous a tap will occasionally cause the mercury to rebound to an erroneously high reading.

C. EMERGENT STEM CORRECTION

The scale corrections for these thermometers are reported for the condition of immersion to the depth of the immersion mark (95 mm), and for the temperature of the emergent stem as reported on the Report of Calibration. The emergent stem is defined as the length of mercury column and stem exposed to the ambient temperature. The temperature of the laboratory was 23 °C when the measurements were made. If the thermometer is used under stem-temperature conditions other than that specified, the formula given below will provide the appropriate correction, which should be added to the thermometer reading along with the correction from the Report of Calibration to produce the true temperature.

$$\text{stem correction} = 0.00016\ n\ (t_{sp} - t_{obs}),$$

where

0.00016 = differential expansion coefficient of mercury in glass for Celsius thermometers,

t_{sp} = specified mean temperature of the emergent stem (for which reported scale corrections apply)

t_{obs} = observed mean temperature of the emergent stem,

and n = number of scale degrees equivalent to the length of emergent stem.

In using the formula it should be noted that n applies to the whole length of emergent stem, i.e., from the immersion mark to the top of the mercury column. The ungraduated length between the immersion mark and the first graduation on the scale must, therefore, be evaluated in terms of scale degrees and included in the value of n.

To measure the emergent stem temperature, a small auxiliary thermometer, generally 15 cm long with a range from 0 °C to 100 °C and graduated in 1 °C intervals, is suspended above the bath adjacent to the main thermometer, with the bulb approximately at the center of the liquid column.

For SRM 933, it will be noted that there would have to be a temperature difference of at least 2 °C to produce approximately a millidegree

change in the thermometer reading. In this example n ≈ 2.6

stem correction = 0.00016 x 2.6 x ± 2

= ± 0.0008 °C

For SRM 934, a 2 °C difference would produce the following results, assuming n approximately equals 4.4, 9.4 and 16.4 for 25 °C, 30 °C, and 37 °C,

Temperature		Correction
25 °C	0.00016 x 4.4 x ± 2 =	±0.0014 °C
30 °C	0.00016 x 9.4 x ± 2 =	±0.0030 °C
37 °C	0.00016 x 16.4 x ± 2 =	±0.0052 °C

To help clarify any difficulty that may remain, an example of how to apply the corrections is given below:

Thermometer = SRM 934,

The reading of the thermometer (immersed 95 mm in the bath) = 30.013 °C,

Measured emergent stem temperature = 29 °C,

Number of degrees from immersion mark to point of reading (30 °C) = 9.4,

Correction on the Report of Calibration at 30 °C = -0.019 (stem temp. = 26 °C).

An ice point check produced the same result as shown on the Report of Calibration.

First find the stem temperature correction:

$$\text{stem correction} = 0.00016 \times n \times (t_{sp} - t_{obs})$$

$$= 0.00016 \times 9.4 \times (26 - 29)$$

$$= -0.005°$$

True temperature = thermometer reading + stem correction + reported correction

$$= 30.013 + (-0.005) + (-0.019)$$

$$= 29.989 \text{ °C}$$

V. SUMMARY AND CONCLUSIONS

In order to obtain the accuracy of temperature measurements of which the thermometers of SRM 933 and SRM 934 are capable, the following items should be closely observed when using them:

1) check for a separated mercury column and gas bubbles in the bulb,
2) check the ice point periodically for changes in the bulb volume,
3) always use the thermometer at the proper immersion (95 mm),
4) correct for emergent stem temperatures different from those listed in the Report of Calibration,
5) gently tap the thermometer before reading,
and 6) read with a telescope, if possible to avoid parallax errors.

With the introduction and use of these SRM thermometers in the typical clinical laboratory, there will be a marked improvement in the laboratory's measurement capability. The thermometers will provide a means by which the laboratory personnel can make a start toward eliminating any uncertainty in their testing which is due to inaccurate temperature measurement and, in many cases, its control. This will assist efforts at improving measurement reproducibility within a given laboratory and intercomparisons among laboratories.

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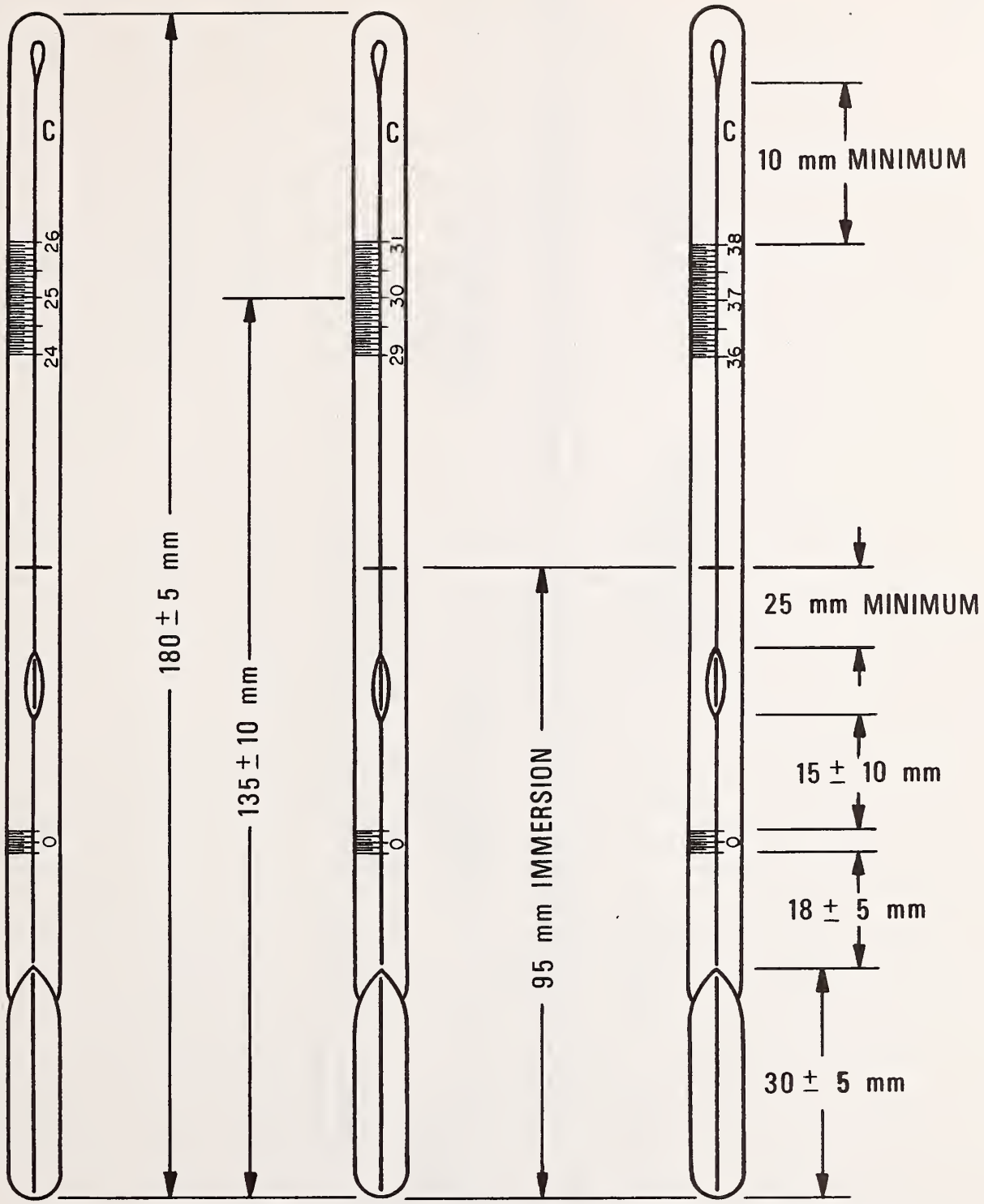

Figure 1. The three thermometers of SRM 933. The subdivisions are 0.05 °C and the graduations have longer lines at intervals of 0.10 °C and 0.50 °C.

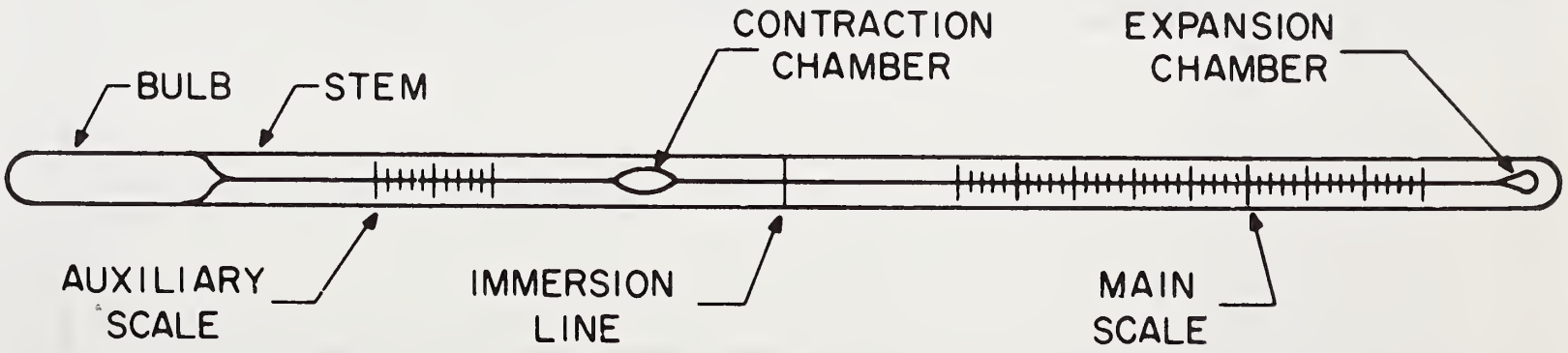

Figure 2. A drawing showing the principal features of a solid-stem liquid-in-glass thermometer.

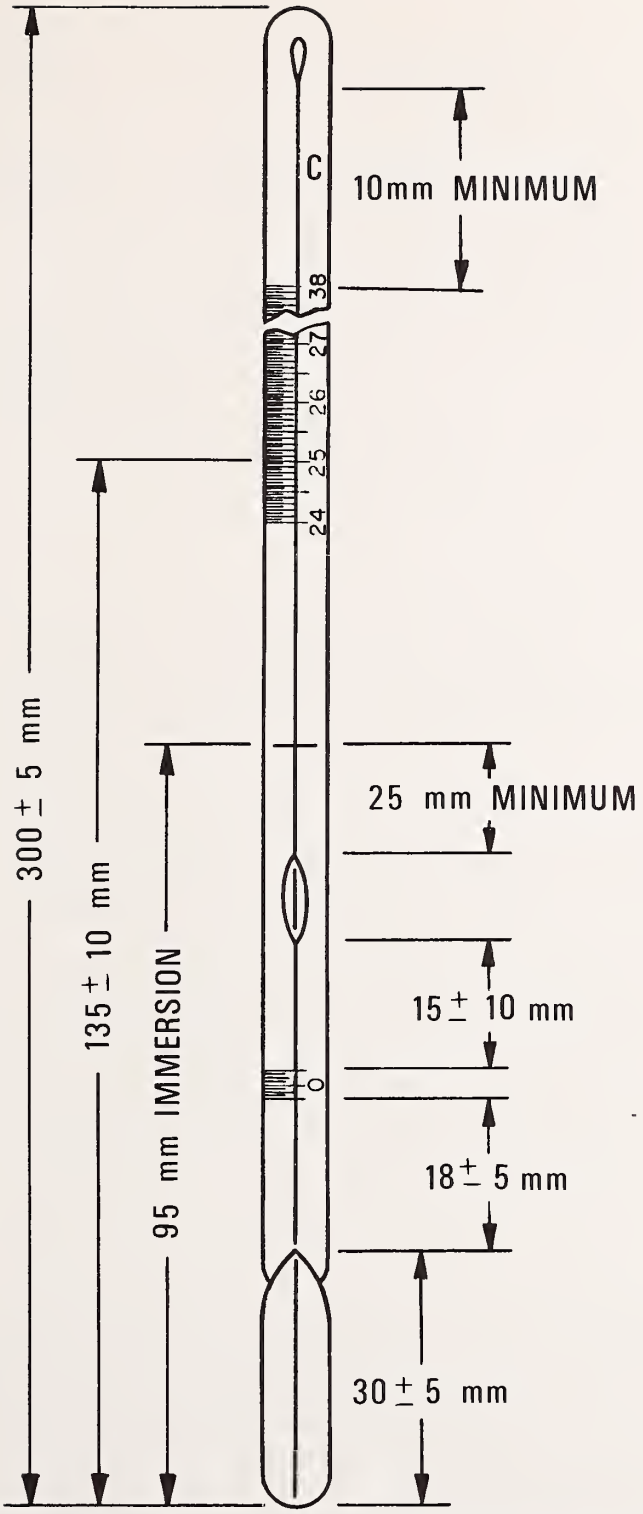

Figure 3. The thermometer of SRM 934. The divisions are 0.05 °C and the graduations have longer lines at intervals of 0.10 °C and 0.50 °C.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Because of the high sensitivity to temperature of many facets of the clinical laboratory, e.g. in enzyme reactions and in pH and blood gas analysis, there is a need for accurate temperature measurements and its control. In order to help satisfy these needs and to aid in getting a usable and accurate temperature scale into the clinical laboratory, the National Bureau of Standards has developed SRM 933 and SRM 934. These are precision thermometers, which are calibrated at 0 °C, 25 °C, 30 °C, and 37 °C and their description, their calibration, and the procedures for their proper usage are discussed.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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